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(58) Field of search
H1B
H2H
Selected US specifications from IPC sub-classes H01M
H02J

(54) Method of recharging a sealed lead-acid storage battery

(57) In the method, a sealed lead-acid battery which has been charged by causing a current to flow thereinto in a charging direction is subjected to a first step in which current is caused to flow into the battery in a direction opposite to the previous charging direction, followed by a second step in which the battery is recharged with constant-voltage, constant-current or semi-constant voltage by causing a current to flow into the battery in the previous charging direction. The method improves recovery of battery capacity of batteries which have remained in an overdischarged state for extended periods and then charged conventionally prior to the application of the present method. The first step may be effected by applying $-2.45V$ to the battery for one minute, $+2.45V$ being applied in the second step.

FIG. 1

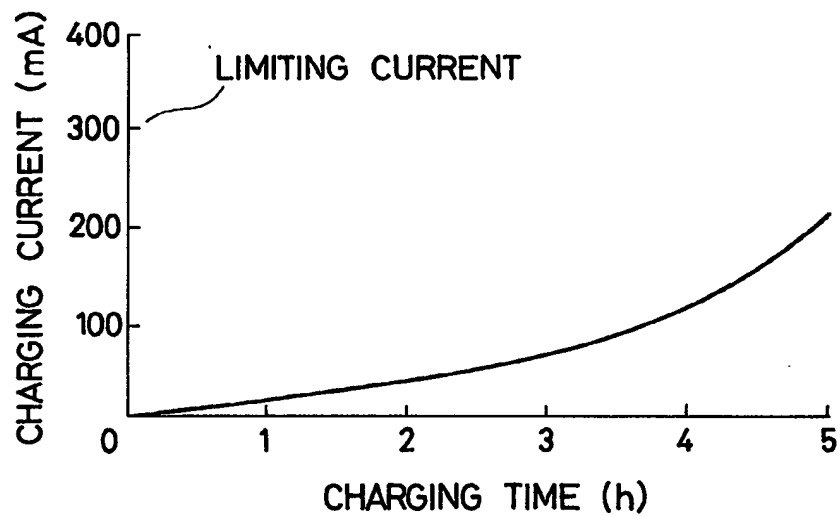
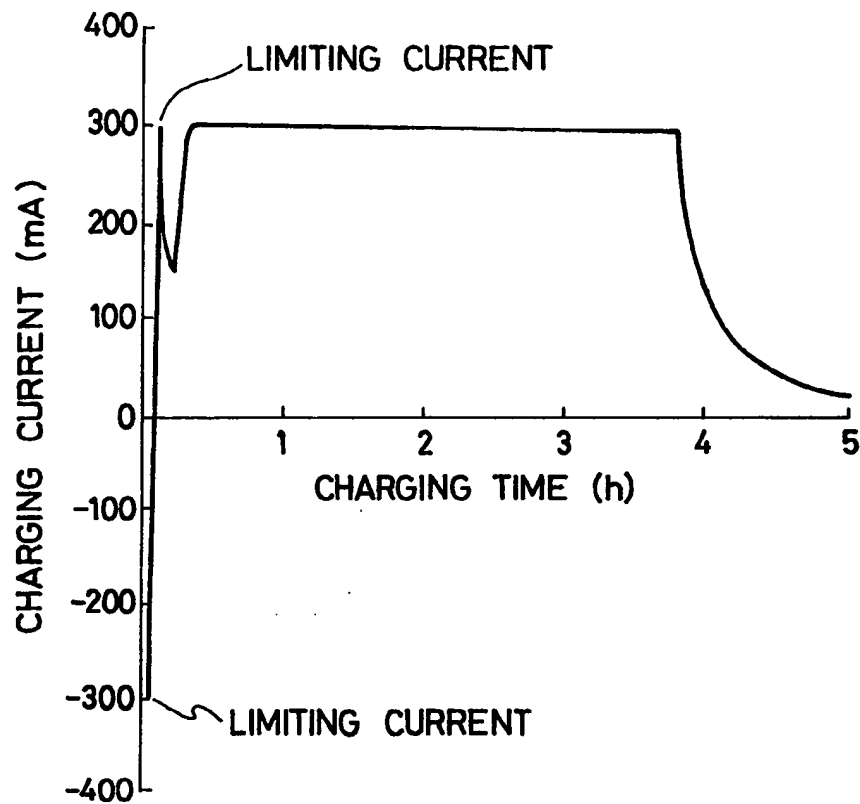


FIG. 2



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FIG. 3

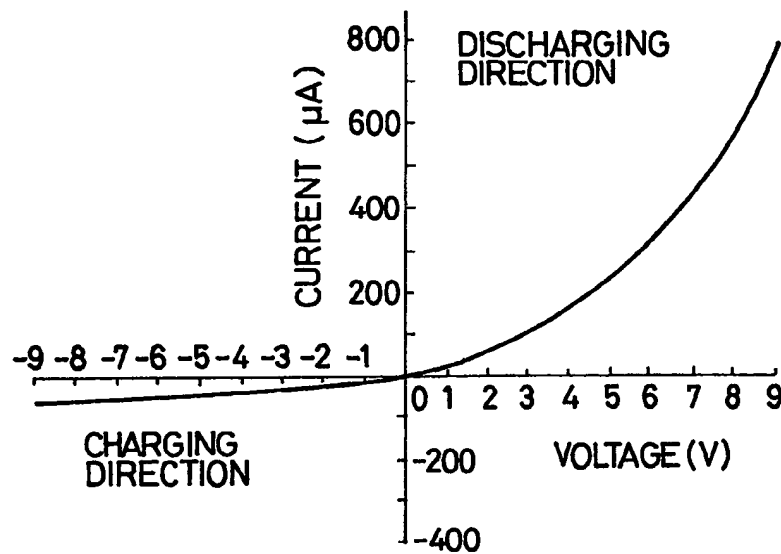
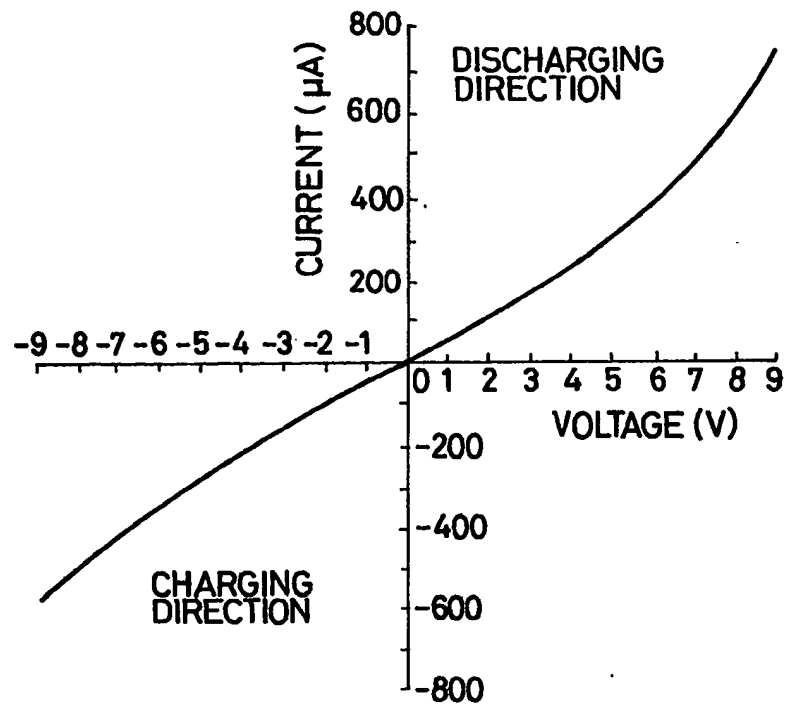


FIG. 4



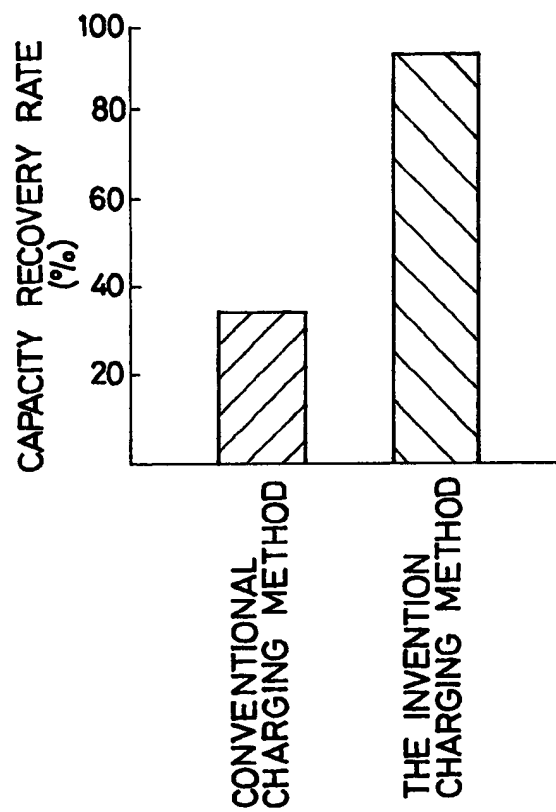
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FIG. 5



SPECIFICATION

Method of recharging a sealed lead-acid storage battery

- 5 This invention relates to a method for charging a sealed lead-acid storage battery, and more particularly to an improvement in a method for recovering charging properties after the battery has been remained overdischarged.
- 10 Constant-voltage charging, constant-current charging or semi-constant-voltage charging method have conventionally been performed as a charging method for a sealed lead-acid storage battery.
- In the aforesaid case, no serious problem has
- 15 been raised so far as normal charging is concerned. However, when such charging is applied to the battery overdischarged, only a very small amount of charging current is allowed to flow after the commencement of charging and therefore,
- 20 sufficient recovery properties within the given period of time is not obtainable. The reason for this is attributed to a high resistance film formed during overdischarge at the interface between the grid of an anode plate and active material.
- 25 In the meantime, the sealed lead-acid storage battery is expected to be increasingly of wide use as a power supply for handy cleaners, VTRs, compact discs, etc. Such demand requiring the lead-acid batteries as power supply is deemed to be much
- 30 more increased in this field of home electric appliances. Since the battery for use in each of such home electric appliances is intended for many and unspecified users, it is often the case with the battery overdischarged for hours and days, and this
- 35 has posed a serious problem because the battery is hardly chargeable through the conventional charging method.
- An object of the present invention is to provide a method for improving battery capacity recovery
- 40 properties in case the battery has been remained overdischarged for a long period of time.
- In order to accomplish the aforesaid object, according to this invention, a sealed lead-acid storage battery, which has been charged by causing
- 45 current to flow thereunto in a predetermined direction, is recharged by:
- causing a current to flow into said battery in a direction opposite to said predetermined direction; and
- 50 then recharging said battery by causing a current to flow thereinto in said predetermined direction.
- Thus in the initial recharging step the polarity of the battery is charged and then conventional constant-voltage, constant current, or semi-constant
- 55 voltage charging takes place.
- The high resistance film formed at the interface between the grid of the anode plate and the active material during the battery being overdischarged has properties similar to those of a diode and no
- 60 ohmic contact is established therebetween. That is, there exists a rectification action. Investigation has been made on current-voltage characteristics in a dried electrode plate undergoing overdischarge. As a result, as shown in Fig. 3, the rectification action
- 65 makes it difficult for the current to flow in the

- charging direction of the battery i.e., from the lead grid to the high resistance film, but easy in the discharging direction, i.e., from the high resistance film to the lead grid. If the current is firstly made to
- 70 flow in the discharging direction, the formation of the high resistance film is changed because of electrochemical reaction, and the rectification action has been proved removable. Fig. 4 shows current-voltage characteristics of a dried electrode plate in
- 75 which the current has been made to flow in the discharging direction. By causing the current to flow in the discharging direction opposite to the charging direction at the commencement of charging, the rectification action of the high resistance film is
- 80 eliminated and after that, when the normal charging is carried out, the current for charging is made to readily flow, whereby charging recovery properties are greatly improved.

In the accompanying drawings:—

- 85 Fig. 1 is a graph showing a curve representing the relationship between charging current and time for charging a battery subjected to overdischarge according to a conventional method, e.g., 2.45 V constant-voltage charging.
- 90 Fig. 2 is a graph showing a curve representing the relationship between charging current and time for charging a battery subjected to overdischarge according to the present invention.
- Fig. 3 is a graph showing current-voltage
- 95 characteristics in a dried electrode plate upon overdischarge.
- Fig. 4 is a graph showing current-voltage characteristics in a dried electrode plate when the voltage of -2.45 V is applied to the battery
- 100 overdischarged, and current is made to flow in the discharging direction for one minute.
- Fig. 5 shows a comparison in capacity recovery rate between the conventional charging method and a method of the present invention.
- 105 An embodiment of the present invention will be described in detail.

- There was prepared a sealed lead-acid storage battery of a 1.2 Ah -2 V type. The battery includes two plates as an anode plate each having a size of
- 110 $28\text{ mm} \times 27\text{ mm} \times 3.4\text{ mm}$, and three plates as a cathode plate each having a size of $28\text{ mm} \times 27\text{ mm} \times 2.4\text{ mm}$. An unwoven glass fabric retainer is used as a separator having thickness of 1.3 mm. At that time, 12 ml sulfuric acid
- 115 having a specific gravity of 1.30 was used as an electrolyte. The battery was charged and discharged several times, and when its capacity was stabilized, then discharge was made by 300 mA, to provide a condition of the battery prior to its overdischarge.
- 120 Then, the battery was subjected to 2.45 V constant-voltage charging for 5 hours, and thereafter the battery was continuously subjected to $5\text{ }\Omega$ constant-resistance discharging for 36 hours. The battery thus overdischarged was further left at
- 125 20°C for 80 days. Fig. 1 shows a current-time fluctuation when the battery thus overdischarged is charged with 2.45 V constant-voltage.
- Fig. 2 shows a current-time fluctuation when the battery was charged with 2.45 V constant-voltage
- 130 after the voltage of -2.45 V was applied to the

battery with the current flowed in the discharging direction for one minute. As shown in Fig. 2, the battery into which the current has been applied in the discharging direction for only one minute according to the present invention allows a large amount of charging current to flow at the 2.45 V constant-voltage charging. The current value is several ten times as large as the value obtained from the conventional 2.45 V constant voltage charging only. Fig. 5 shows a comparison between capacity recovery rates when conventional 2.45 V constant-voltage charging has been carried out for 5 hours and when 2.45 V constant-voltage charging has been carried out for 5 hours after applying the voltage of -2.45 V with the current flowed in the discharging direction for one minute according to the present invention. As is obvious from Fig. 5, the recovery rate according to the invention has been greatly improved in comparison with the conventional method. It is still unknown why the rectification action occurs at the interface between the grid of the anode plate and the active material of the battery overcharged, and why the rectification action is nullified if current is once made to flow in the discharging direction. However, the rectification action is considered to be eliminated because of the morphological change of the film, which change is attendant to the electromechanical reaction in the sulfuric acid. Such consideration is due to the fact that the rectification action is not nullified in the dried state even though the current direction is changed without employment of the sulfuric acid. The measured internal resistance of the battery was about 500 Ω after the battery was overcharged, and about 2 Ω after the voltage of -2.45 V was applied to the battery to flow a current in the discharge direction for one minute. In consequence, the form of the resistance film has obviously been submitted

to change.

40 Although the constant-voltage charging has been employed for charging by changing the final polarity according to the present embodiment, it has also been confirmed that the semi-constant voltage charging or constant-current charging is also effective in recovery of charging properties in the case of the sealed lead-acid storage battery overcharged.

As set forth above, the method for charging the sealed lead-acid storage battery according to the present invention is effective in recovery of charging properties.

The present invention would provide highly industrial significance since overdischarged lead-acid storage batteries will be brought into attention for the application of electrical discharge.

CLAIMS

1. A method of recharging a sealed lead-acid storage battery which has been charged by causing a current to flow therinto in a predetermined direction, the method comprising the steps of: causing a current to flow into said battery in a direction opposite to said predetermined direction; and

65 then recharging said battery by causing a current to flow therinto in said predetermined direction.

2. A method as claimed in Claim 1, wherein said battery is charged with a constant-voltage.

3. A method as claimed in Claim 1, wherein said battery is charged with a constant-current.

4. A method as claimed in Claim 1, wherein said battery is charged with a semi-constant-voltage.

5. A method as claimed in Claim 1, substantially as described with reference to the accompanying

75 drawings.